If an ectodermal origin of the antennary and maxillary glands be confirmed in crustacea generally, then we should be led to regard these structures as nephridia, which have lost their primitive connection with a cœlom, and the end-sac would be looked upon as equivalent to the "flame-cell" of a typical intracellular nephridium.

The above preliminary account, which has omitted all reference to the nervous system and sense-organs, is merely a summary of the results already obtained. I hope in a future publication to give a full account, containing careful drawings with the camera lucida.

"The Growth of Magnetism in Iron under Alternating Magnetic Force." By ERNEST WILSON. Communicated by Professor J. M. THOMSON, F.R.S. Received February 25,—Read March 28, 1901.

The object of this paper is to investigate the growth of magnetism in an iron cylinder when the magnetising force is alternating. The shielding effect of induced currents in plates of iron has been dealt with theoretically by Professor J. J. Thomson,[*] and Professor J. A. Ewing.[†] The subject has also been dealt with experimentally in the case of an iron cylinder, 4 inches diameter,[‡] with alternating magnetising force and with simple reversal of the magnetising force. A cylinder, 12 inches diameter, has been experimented upon with simple reversal of magnetising force,[§] and the shielding effect of induced currents studied. As the exploring coils enclosing elements of the cross-section of this 12-inch magnet are well suited to give the average induction density at four mean radii, the author thought the subject worth further investigation with regard to alternate currents. The magnet is of cast steel, and is shown in sectional elevation in fig. 1. A section of the 12-inch core on the line AA is given in fig. 2. Wires have been threaded through the holes drilled in the plane AA, enclosing the areas numbered 1, 2, 3, 4 (fig. 2), and another coil (No. 5) surrounds the core. A D'Arsonval galvanometer was placed in each of these five circuits with an adjustable resistance to control the maximum deflection. The deflections of the needles of the five galvanometers were noted simultaneously every four seconds, and were ultimately plotted in terms of time. The magnetising current in the copper coil of the magnet was observed simultaneously with the above on a Weston ampere meter. The current was made to alternate

by means of a liquid ($CuSO_4$ dil.) reverser consisting of two oppositely fixed copper plates, each embracing a quadrant of a circle, and two similarly shaped copper plates fixed to a vertical spindle and capable
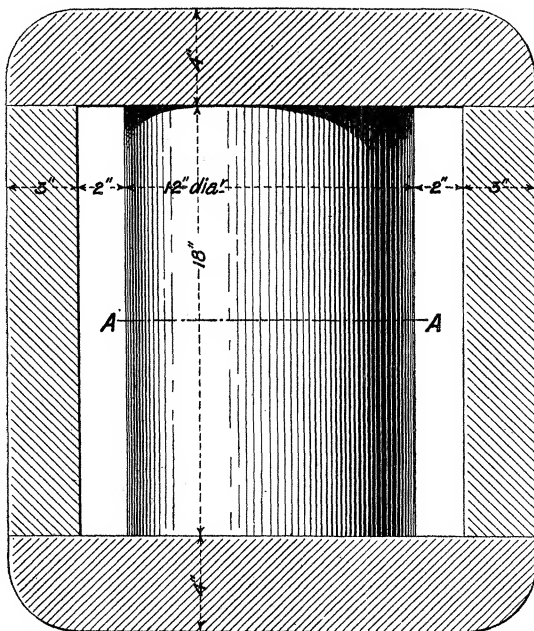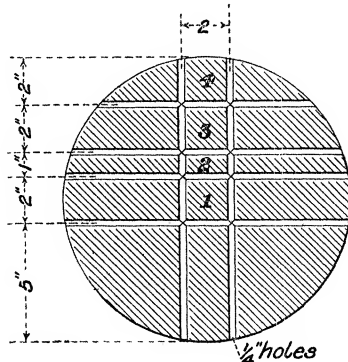
Fig. 1.

Fig. 2.

of rotating concentrically within the fixed plates. The operator at this liquid reverser counted seconds aloud whilst listening to the ticks of a seconds pendulum. In this way the epoch for all the observa-

tions could be noted. The speed of rotation was varied, from one revolution in ten to one revolution in two and a half minutes.

The electromotive force curves have been integrated, and therefrom the maximum average induction per sq. cm. of the area considered has been obtained. The data are set forth in the appended table. Since similar magnetic and electric events will happen in different sized cylinders at times varying inversely as the square of their linear dimensions, it is easy to infer what will happen in a cylinder 1 mm.
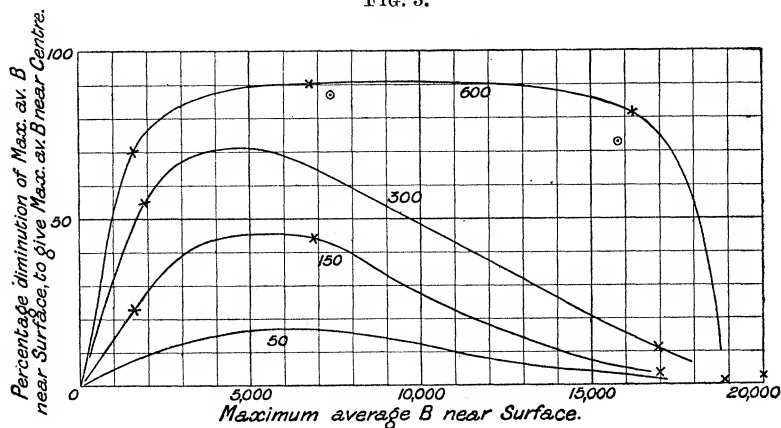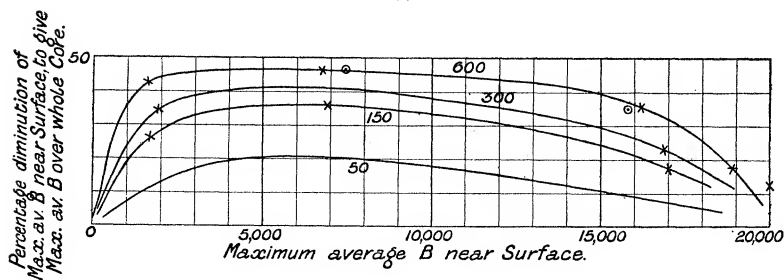
FIG. 3.

FIG. 4.

diameter. Similar events will happen in this wire at 150 periods per second, as have been observed in the 12-inch core with a periodic time of ten minutes. A useful way of illustrating the results obtained is to express in the form of curves the relation between the maximum average B over Area No. 4, that is, near the surface of the core, and the percentage amounts by which this maximum has to be reduced to give (1) the maximum average over Area No. 1, and (2) the maximum average over the whole core as given by coil No. 5. This is done in figs. 3 and 4, in which the number on each curve refers to the

frequency with a 1 mm. wire. Figs. 5 and 6 show the relation between the frequency in complete periods per second for a 1 mm. wire and the same two quantities respectively. Since a plate, with regard to
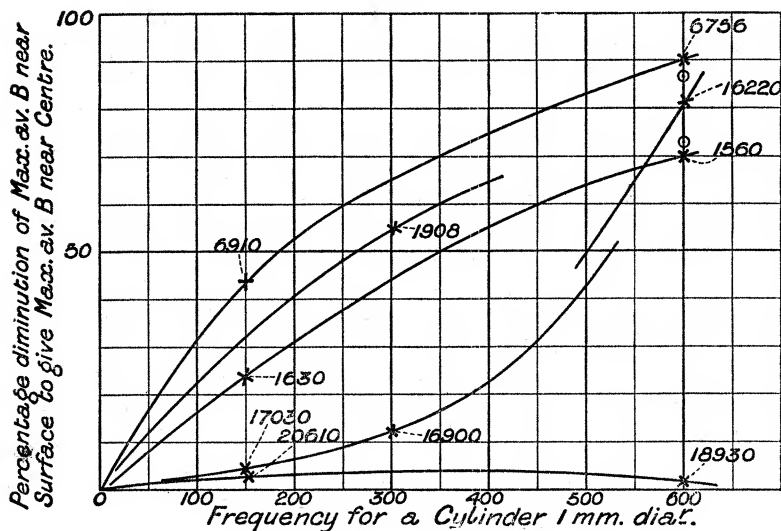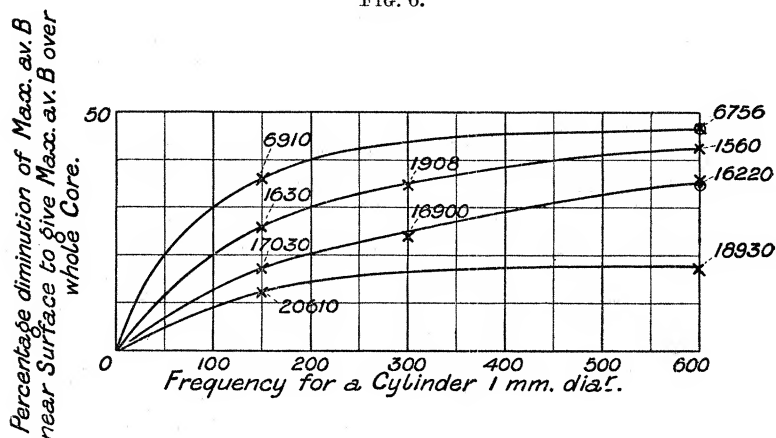
Fig. 5.

Fig. 6.

induced currents in its substance, is comparable to a wire, the thickness of the plate being half the diameter of the wire, the above curves may be taken to apply also to a $\frac{1}{2}$ mm. plate. In figs. 3, 4, 5, 6 the points indicated by × are the result of experiment when the magnet had a temperature of about 15° C.

Suppose a transformer core to be built up of 1 mm. wires, or $\frac{1}{2}$ mm. plates, insulated from one another, the transformer being in action with no currents in its secondary circuit.   The reaction of the core upon the primary or magnetising coil will be the rate of change of the average induction over the whole core.   The average induction per sq. cm. of a particular wire or plate will differ from the induction per sq. cm. at the surface of such wire or plate by an amount varying with the frequency and with the value of B at the surface.   For high and low values of the surface B and a given frequency the average over the whole wire or plate differs less from the maximum at the surface than for intermediate values of the surface B.   The relation between the permeability of the iron and the rate of propagation of magnetism in the iron has been explained in the case of simple reversals,* and agrees with what we have just observed.   When the limits of B are small, that is, the permeability is small, the magnetism is propagated rapidly.   For intermediate values of the limits of B, that is, when the average permeability is large, the rate of propagation is small.   With the high limits of B the average permeability is small and the magnetism is propagated more rapidly.   Setting aside the subject of magnetic viscosity, we should expect the average B over the whole wire or plate to be equal to the surface B if these induced currents did not exist. The curves show that for a given frequency there is an effect which increases the extent to which equalisation of the induction density over the core may be carried according as the maximum limits of B at the surface are on the lower or higher part of the curve of induction of the material.   The dissipation of energy, due to magnetic hysteresis and induced currents, will likewise be affected since uniform distribution gives minimum dissipation for the same maximum average induction over the whole core.

Not only have we to consider the maximum value of the induction density at different parts of the core, but the phase of such induction density.   It is not necessary to publish all the curves obtained, but as an example one might contrast in figs. 7 and 8 the curves of E.M.F. obtained with periodic times of 10·3 and 2·6 minutes for about the same maximum magnetising force, namely, 9·6 and 9·5.   In figs. 7 and 8 the E.M.F. curves are plotted to a scale giving C.G.S. units per sq. cm. of the area embraced by the respective coils, the curve number corresponding with the coil number in fig. 2.   With 10 minutes' periodic time the induction is practically reversed over the whole core by the time the current has attained its maximum value ; whereas with 2·6 minutes' periodic time the current is again zero when the innermost coil (No. 1) is experiencing its maximum E.M.F.   In the first case nearly the whole of the change for each coil aids the average

* Hopkinson and Wilson, 'Journal of the Inst. Elec. Eng.,' vol. 24, p. 195.
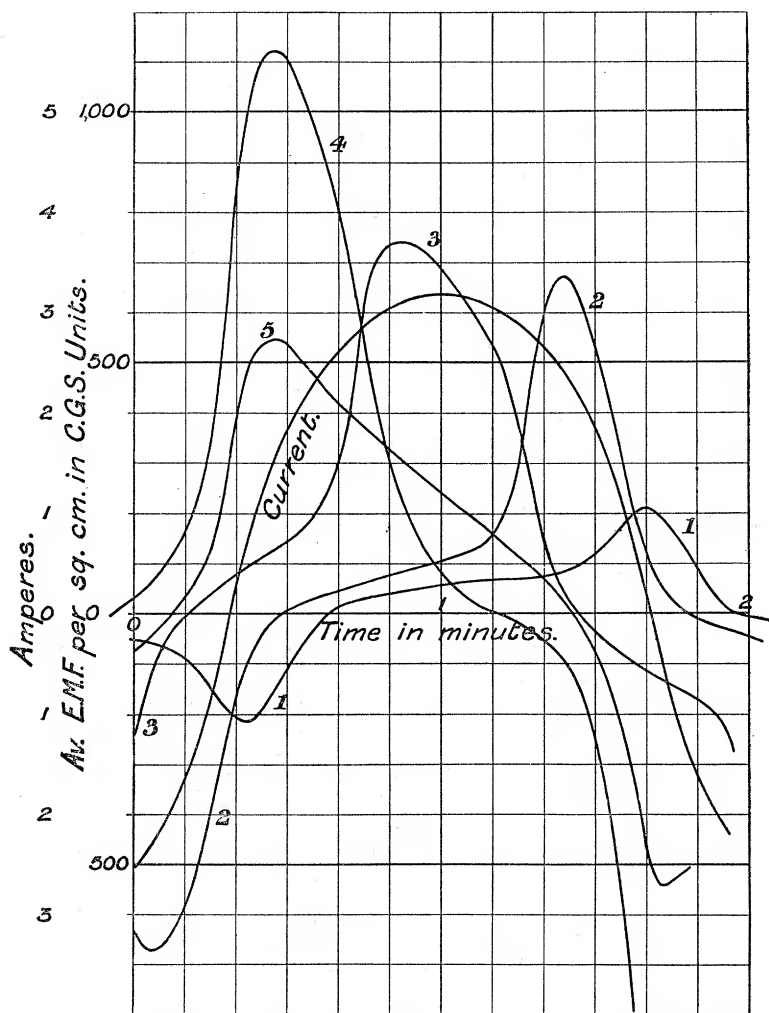
Fig. 7.
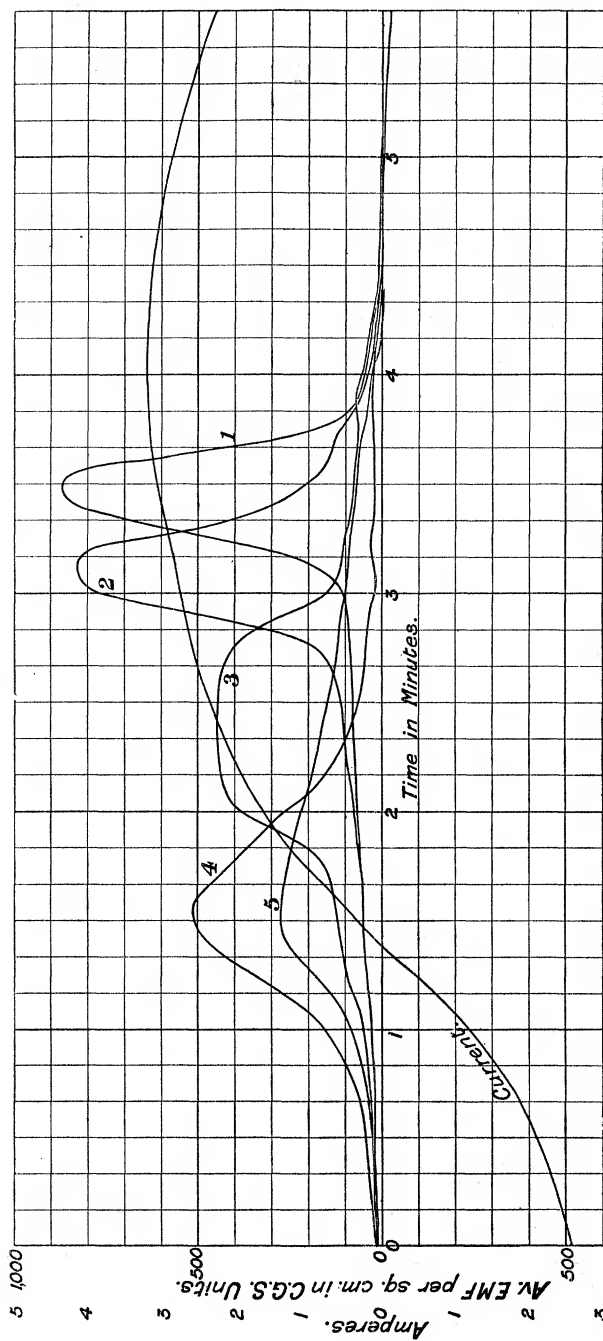
(No. 5) E.M.F. In the second case the areas inclosed by Nos. 1 and 2 coils oppose, and the average suffers accordingly.

It is of interest to see what effect raising the temperature of the
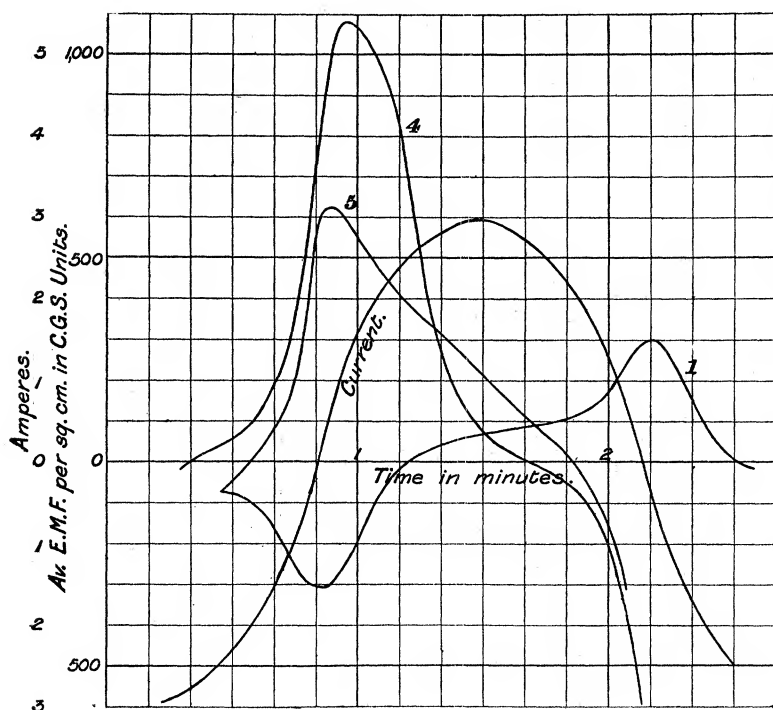
FIG. 8.

magnet would have upon these induced currents. The magnet was heated by placing Fletcher gas furnaces around it. The heat was applied for about $1\frac{1}{2}$ hours, and the magnet allowed to cool. The electrical resistance of the No. 1 coil was measured, and when it

became steady, indicating a temperature of about 53° C., two sets of curves were taken. The points obtained with the heated magnet are indicated by ⊙ in figs. 3, 4, 5, 6. In fig. 9 the curves obtained at

FIG. 9.

53° C. with a maximum magnetising force H of 8·85, and periodic time 2·6 minutes, are given in order to enable a comparison to be made with fig. 8. It will be seen that coil No. 1 has an E.M.F. somewhat retarded at the higher temperature. The E.M.F. of this coil also suffers retardation of phase in the experiment with the lower force 2·85, when the magnet is at the higher temperature.

Heating the magnet has had the effect of increasing the maximum average value of B at the centre for the same frequency and slightly smaller magnetising force of the same wave-form. The relation between the surface density (No. 4 coil) and the average obtained from coil No. 5 remains practically the same. In this connection it should be remembered that for the same average over the whole core, a considerable increase in the induction density at the centre is compensated by a small decrease at the surface. It appears, then, that raising the temperature of the magnet tends to equalise the maximum

Maximum average Induction per sq. cm. in C.G.S. units.

Coil	Average radius in cms.	Temperature of Magnet about 15° C.										Temperature of magnet about 53° C.	
1	0	1,260 / 874	863 / 600	472 / 328	3,847 / 2,670	653 / 474	16,460 / 11,400	15,020 / 10,400	3,010 / 2,090	20,000 / 13,880	18,800 / 13,050	951 / 660	4,305 / 2,990
2	3·97	—	—	—	5,555 / 2,640	1,040 / 495	18,200 / 8,660	17,050 / 10,400	7,950 / 3,780	22,000 / 10,500	21,100 / 10,050	—	—
3	6·72	—	—	—	6,710 / 4,660	2,520 / 4,750	19,110 / 13,300	17,900 / 12,400	13,930 / 9,670	21,900 / 15,200	20,100 / 14,000	—	—
4	12·7	1,630 / 1,271	1,908 / 1,488	1,560 / 1,217	6,910 / 5,390	6,756 / 5,270	17,030 / 13,280	16,900 / 13,200	16,220 / 12,650	20,610 / 16,080	18,930 / 14,770	7,330 / 5,720	15,780 / 12,370
5	—	1,200	1,260	884	5,085	3,617	14,140	13,020	10,420	17,870	15,500	3,910	10,240
Periodic time in minutes		10·3	5·2	2·6	10·3	2·6	10·3	5·1	2·6	10·3	2·6	2·6	2·6
Max. H due to magnetising current in copper coils		1·1	1·1	1·1	2·82	2·83	9·6	9·45	9·51	16·7	16·9	2·85	8·85
Frequency for a wire 1 mm. dia. meter		150	300	600	150	600	150	300	600	150	600	600	600
Percentage diminution of max. av. B in Coil 4 to give max. av. B over whole area—Coil 5		26 / 5·6	34 / 15·3	43 / 27·4	36 / 5·7	46·5 / 31·7	17 / −6·5	23 / 1·4	36 / 17·6	13 / −11	18 / −4·9	46·7 / 31·6	35 / 16·8
Percentage diminution of max. av. B in Coil 4 to give max. av. B at centre of core—Coil 1		23 / 31·2	55 / 59·7	70 / 73·1	44 / 50·5	90 / 91	3·3 / 14·2	11 / 21	81 / 83·5	3·0 / 13·7	0·7 / 11·6	87 / 88·4	72·7 / 75·7

Fig. 7.

Fig. 8.

Fig. 9.

induction density over its section. On account of the increased lag of phase of induction as the centre is approached, the maximum average over the whole core is not materially altered for the same surface density. The force due to the current in the magnetising coils is smaller at 53° C. for the same maximum average induction density over the whole core. For a given permeability and hysteresis loss the higher the specific resistance and temperature coefficient the better.

It should be mentioned that the potential difference employed in these experiments was 200 volts, the excess over the magnet and liquid reverser being taken up by non-inductive resistance. The area taken for each coil is the actual area of iron in the plane of section, fig. 2. The areas taken for coils 1, 2, 3, and 4 are 19·8, 8·465, 19·8, and 21·16 sq. cm. respectively. If, instead of these, we take the areas bounded by the centre lines of the $\frac{1}{4}$-inch holes, the diminution of induction density would be 30·6, 52·4, 30·6, and 22 per cent. respectively. The true correction will not alter the general conclusions arrived at in the paper, and is a function of the permeability of the iron. The figures in the table in italics are the result of taking the increased areas, so that a comparison can be made. The D'Arsonval galvanometers used have slightly different dead-beatness. The least and most dead-beat instruments were placed in series in the No. 1 circuit, when the changes of E.M.F. were most rapid. The instruments gave the same result within the limits of error in observation. A variable still to be dealt with is the wave-form of the magnetising currents.

FIG. 1.

FIG. 2.

2 holes